International Orthopaedics (SICOT) (2004) 28:48–51
DOI 10.1007/s00264-003-0502-5

ORIGINAL PAPER

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Muscle performance after anterior cruciate ligament reconstruction

Accepted: 1 July 2003 / Published online: 26 August 2003

Abstract We measured muscle strength in 36 patients after anterior cruciate ligament (ACL) reconstruction with autogenous bone-patellar tendon-bone graft. Quadriceps and hamstring isokinetic strength was assessed during concentric contraction at 60 and 180°/s and was measured at 1, 6, 12 and 24 months postoperatively. At 24 months quadriceps muscle strength had recovered to approximately 90% of the level of the uninvolved side, both at 60 and 180°/s. In contrast, hamstring muscle strength had already recovered to approximately 90% at 6 months. Age, gender, activity level, and anterior tibial laxity did not affect the muscle performance. However, the recovery of muscle strength was delayed in patients with anterior knee pain.

Résumé Nous avons mesuré la force musculaire chez 36 malades après reconstruction du LCA avec autogreffe "os-tendon rotulien-os". La force isokinétique du quadriceps et des ischio-jambiers a été étudiée pendant la contraction concentrique à 60 et 180 degré/sec et a été mesurée à 1, 6,12 et 24 mois postopératoires. À 24 mois la force musculaire du Quadriceps avait retrouvé approximativement 90% de la force du côté opposé, à 60 et 180 degré/sec. Par contraste, la force musculaire des ischio-jambiers avait déjà retrouvé 90% de sa valeur à 6 mois. L'âge, le sexe, le niveau d'activité, et la laxité tibiale antérieure n'ont pas affecté la performance musculaire. Cependant la récupération de force musculaire a été différée chez les malades avec douleur antérieure du genou.

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Introduction

A complete anterior cruciate ligament (ACL) rupture is a severe trauma to the knee joint [4]. The bone-patellar tendon-bone (BTB) autograft technique is considered the gold standard for repair [3, 11] because of its strength [8] and adequate stability [17]. Many follow-up studies after ACL reconstruction using BTB demonstrated good results in knee stability, a high rate of return to sports, preservation of motion, and subjective assessment scores [1, 18]. Harvesting the patellar tendon (PT) for autograft ACL reconstruction does not diminish quadriceps strength and functional capacity [6]. However, patients with ACL reconstruction still experienced permanent weakness, functional deficits, and postoperative pain [13], and patellofemoral osteoarthritis and anterior knee pain (AKP) after ACL reconstruction have recently received attention [16]. Despite the surgical achievement of ligamentous stability, some patients still experience permanent weakness of the thigh muscle, functional deficits, a decline in sports activity, and AKP after ACL reconstruction with PT autograft.

The goal of ACL reconstruction cannot be achieved without recovery of muscle strength, even if the knee has regained good stability and sufficient range of motion [10]. Many reports show that muscle performance after ACL reconstruction improved with time. Natri et al. found the mean quadriceps strength to be 85% compared with the uninvolved knee with PT graft on average 4 years postoperatively [9]. Marder et al., in their postoperative study of patients with PT graft, found that the recovery of mean quadriceps strength was 88% at a minimum of 2 years postoperatively [7]. However, short-term or mid-term postoperative muscle strength was examined in these reports. Relatively few studies critically evaluated the performance of the quadriceps periodically after ACL reconstruction. Moreover, the postoperative recov-

ery pattern of the muscle performance is not clearly understood.

Only a few studies have systematically examined which general, biomechanical, or functional parameters may predict the outcome after ACL surgery [9]. If we could define outcome-predicting factors, surgery results would be further improved.

This study evaluated thigh-muscle performance after ACL reconstruction using autogenous BTB graft and also analyzed the predictive factors influencing the recovery of thigh-muscle strength.

Material and methods

The study subjects were 36 patients with an isolated, complete rupture of the ACL that had been treated surgically between January 1995 and May 1997. There were 11 men and 25 women in this study. Mean patient age at surgery was 23.5 (14–45) years. The mean interval from injury until surgery was 19 (1–36) months.

All patients underwent ACL reconstruction using a standard BTB technique, the procedure was arthroscopically assisted using a single incision. In all patients, a continuous passive motion device (Sutter, San Diego, CA, USA) was used from the second postoperative day. Partial weight bearing was begun during the second postoperative week with gradual advancement to full weight bearing during the fourth postoperative week. Running was begun between the third to fourth postoperative months, and cutting motion exercises were begun at the sixth postoperative months. Return to full sports activities was allowed on achievement of at least 70% quadriceps strength compared to that of the opposite limb, in the absence of hydrarthrosis, and obtaining a full range of motion.

Muscle strength during an isokinetic exercise was measured using the Biodex dynamometer (Biodex, Shirley, NY, USA). Patients were fixed to the testing apparatus with straps around the chest, pelvis, and thigh. We adjusted the height of the seat to align the posterior one third of the tibiofemoral joint with the axis of the rotation of the dynamometer during flexion-extension motion of the knee. A resistance pad was placed over the distal one third of the lower leg, without restricting ankle dorsiflexion or plantar flexion. All strength measurements were corrected for the effects of gravity on the lower-leg segment and the resistance pad of the dynamometer. The isokinetic strength measurements of the quadriceps and hamstring muscles were at a velocity of 60 and 180°/s. Subjects were explained to sufficiently about the device and understood the measurement methods. Each subject was given a 5-min warm-up period by aerobic ergometer cycling.

Preparation consisted of three submaximal repetitions and, the formal testing consisted of five maximal repetitions using the uninvolved extremity first and then the involved side. To analyze the quadriceps and hamstring isokinetic strength, we assessed the mean peak torque of five maximal repetitions, and the results of the operated leg were expressed as a percentage of that of the nonoperated leg. These measurements procedures were performed at 1, 6, 12, and 24 months postoperatively.

Five background variables that were thought to process outcome-predictive factors were selected for the prediction analysis. They were age; gender; activity level (athletic, recreational); anterior tibial displacement measured 2 years postoperatively by stress radiography using a Telos-SE (Fa Telos, Germany) device (<3 mm of laxity compared with the nonoperative leg, 3 mm of laxity); and AKP examined at 1 year postoperatively (marked on kneeling, none). We assessed AKP using the kneeling test according to Webb et al [18]. All data were analyzed by Stat View-j 4.5 (Abacus Concepts Inc., Berkeley, CA, USA). Comparisons of data were performed using unpaired Student's *t* tests and chi-square tests. The level of significance was set at $P<0.05$.

Results

The mean result for knee extension at a velocity of 60°/s was 33.1% at 1 month postoperatively,63.2% at 6 months 72.9% at 12 months, and 89.1% at 24 months. Quadriceps muscle performance slowly recovered with postoperative time. At a velocity of 180°/s, the mean result for knee extension was 69.3% at 6 months postoperatively; 81.8% at 12 months, 90.6% and at 24 months (Fig. 1), similarly recovered with postoperative time. In contrast, the isokinetic flexion performance recovered more rapidly than extension performance. The mean result for flexion at a velocity of 60°/s was 65.5% at one month postoperatively, even if at 6 months postoperatively approximately 90% compared with normal side (Fig. 2). At a velocity of 180°/s the isokinetic flexion

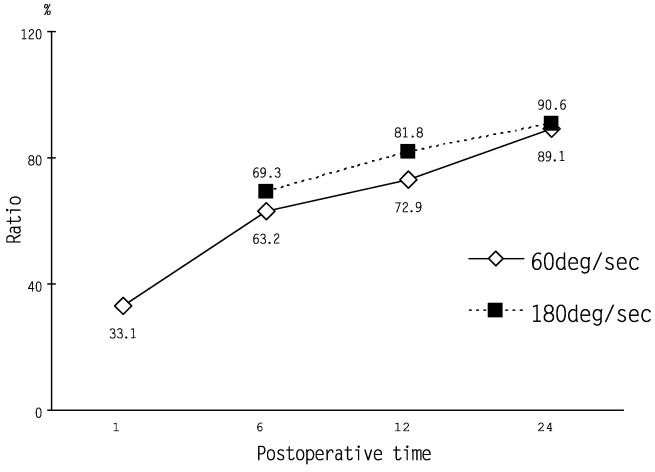

Fig. 1 Isokinetic muscle performance of the quadriceps 1–24 months postoperatively expressed as a percentage of that of the nonoperated leg

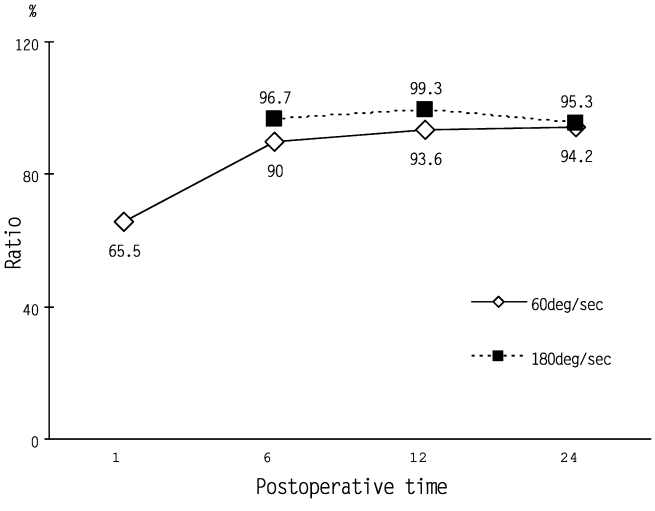

Fig. 2 Isokinetic muscle performance of the hamstrings 1–24 months postoperatively expressed as a percentage of that of the nonoperated leg

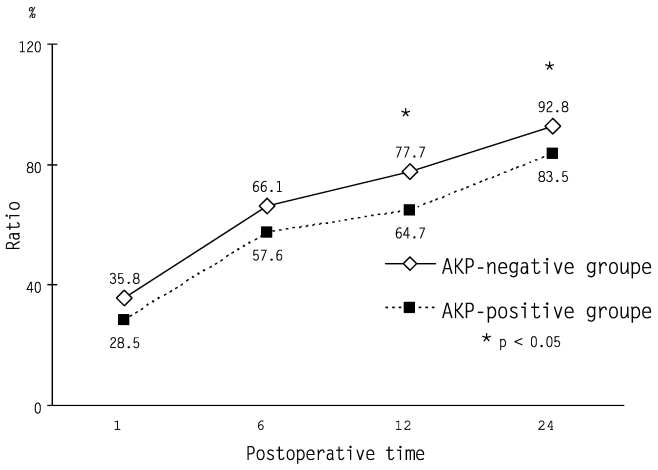

Fig. 3 Isokinetic muscle performance (quadriceps, 60°/s expressed as percentage of that of the nonoperated leg) 1–24 months postoperatively in patients with and without anterior knee pain

performance was similarly recovered with at a velocity of 60°/s.

Analysis of variance showed no significant differences between the group mean of the peak torque deficits within each of the predictive variables (age, activity level, amount of postoperative anterior tibial displacement). However, there was a tendency for the postoperative restoration of quadriceps muscle performance to be more delayed in women compared to that in men, although there were not significant differences between men and women.

Using the kneeling test, 13 patients (two men and 11 women) were classified in the AKP-positive group, while the others (nine men and 14 women) were AKP negative. There was a greater tendency for AKP to occur in women than in men. During the 60°/s isokinetic knee extension, the pain-positive group showed 64.7% recovery compared with the normal side at 12 months postoperatively. In contrast, the pain-negative group was 77.7% at the same time. In addition, the pain-positive group showed 83.5% recovery at 24 months postoperatively; the pain-negative group was 92.8% at that time point. There were significant differences concerning postoperative restoration of the quadriceps muscle performance between the two groups (Fig. 3). In a word, AKP was a postoperative risk factor that affected recovery of the quadriceps muscle performance.

Discussion

Several authors have reported appreciable strength deficiencies at one postoperative period after ACL reconstruction with autogenous BTB graft. Sachs et al. found the mean quadriceps strength to be only 60.8% with BTB graft at 1 year postoperatively [14]. Rosenberg et al., in their postoperative study of patients with patellar tendon autograft, reported that, at 12–24 months, quadriceps strength had recovered to 82% and hamstring strength to 90% [13]. Natri et al. reported quadriceps deficits of 15% and hamstring deficits of 9% in patients with PT graft when evaluated an average of 4.3 years after surgery [9].

In our study, at a velocity of 60°/s, quadriceps deficits of 27% and hamstring deficits of 9%; and at a velocity of 180°/s, quadriceps deficits of 12% and hamstring deficits of 7% were demonstrated 12 months after ACL reconstruction. Quadriceps strength was recovered more slowly than hamstring strength after ACL reconstruction with autogenous BTB graft.

Few studies have reported quadriceps muscle performance periodically after ACL reconstruction. Niga et al. measured the extensor muscle strength periodically—at 3, 6, 9, 12, 15, and 18 months postoperatively. They reported that quadriceps muscle strength recovered with time and recovered to more than 80% with BTB graft at 18 months postoperatively [10].

Our study also showed that quadriceps muscle strength recovered with time. Moreover, we found a muscle-strength increase of 17% at a velocity of 60°/s and 9% at a velocity of 180°/s between 12 and 24 months postoperatively. Quadriceps muscle performance favorably recovered after return to sports.

Some previous reports focused on factors that may affect the recovery of muscle performance after ACL reconstruction. Sachs et al. observed that after ACL surgery, patellofemoral pain was induced by contact force around the patella by the examiner, and flexion contracture was associated with thigh-muscle weakness in the injured extremity [14]. Bach et al. reported a statistical correlation between age and quadriceps deficits [1]. Natri et al. concluded that patellofemoral pain and flexion deficit of the knee joint were risk factors for the recovery of muscle strength [9].

In our study, there was a significant difference in quadriceps muscle performance between the AKP-positive group and the negative group. AKP was a risk factor for recovery of quadriceps muscle strength. Patellofemoral pain symptoms after ACL reconstruction is probably the most common problem. It is complex and can be related to many factors. Buss et al. [2] reported patellofemoral symptoms in 23% of their patients undergoing ACL-reconstruction with PT autograft. Otto et al. [12] reported 17% of 68 patients showed tenderness over the graft site when kneeling. Shelbourne et al. [15]. reported 32% of 602 patients had moderate symptoms and 10% had severe symptoms on kneeling. In our study, 13 of 36 patients (36%) had AKP.

We assessed AKP using the kneeling test according to Webb et al. [18]. This test was performed with the patient kneeling on an examining table and they were asked whether or not they felt pain. We have not yet clarified the cause of AKP. Kartis et al. [5] reported that an injury to the infrapatellar branch of the saphenous nerve after PT graft harvest probably caused problems during crawling on the knees. Shelbourne et al. reported that AKP after ACL reconstruction is caused by

a graft not fitting precisely in the intercondylar notch in normal hyperextension and suggested that the increased incidence of AKP with an autogenous PT graft can be prevented by obtaining full knee hyperextension postoperatively [15].

In our study, 13 of 36 patients had AKP, and 11 of the 13 patients with AKP were women. Though we did not examine the causes of AKP, we are now considering why AKP more frequently occurs in women than men. We suppose that PT graft harvest influences the recovery of quadriceps strength more in women than in men.

When we perform ACL reconstruction with BTB, we need to pay attention to these findings and to improve the postoperative rehabilitation protocol to decrease AKP. We suggest that this will improve the results of ACL reconstruction.

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